Sedentary behaviours and cognitive function among community dwelling adults aged 50+ years

Sedentary behaviours and cognitive function among community dwelling adults aged 50+ years: Results from the Irish Longitudinal Study of Ageing

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Abstract

Background: Sedentary behaviours (SB) are risk factors for poor cardiovascular health and all-cause mortality. However, their role in cognitive health in older adults is unclear. A few studies have examined associations between sedentary behaviours and cognition, but are limited by heterogeneity and insufficient longitudinal analyses. Therefore more robust studies, which would address identified limitations, are needed to accurately determine associations.

Method: This study analysed data collected from participants aged 50+ years of The Irish Longitudinal Study of Ageing (TILDA). We conducted cross-sectional linear regression with multivariate imputation analyses of baseline data from wave 1 (N=8163, weekday-sitting time), and wave 3 (N=6400, weekday-television viewing); longitudinal analyses between waves 1-3 (sitting) and waves 3-4 (television). Sedentary behaviours were analysed as both categorical and continuous variables. Outcome of cross-sectional analyses was standardised regression co-efficient of associations sedentary exposures and cognitive function in respective waves, while for longitudinal analyses was cognitive change (verbal memory, verbal fluency, and global cognition) between waves based on standardised residuals.

Result: Study found significant but mild cross-sectional associations between one-hour increase in weekday-television viewing and poorer verbal memory (b=-0.02, CI:-0.04,-0.003, P<0.05) and verbal fluency (b=-0.02, CI:-0.04,-0.002, P<0.05). Baseline television viewing of 3.5+ hours/day had mild but significant association with a decline in verbal fluency two years later in participants aged 65+ years, when compared with a reference category of <1.5 hours of TV viewing. (b=-0.12, CI: -0.23,-0.001, P<0.05)

Conclusion: Our study findings indicated some association between increased levels of weekday-television viewing time, independent of physical activity, and poor cognition cross-sectionally and longitudinally in middle-aged and older adults. Intervention studies are needed to confirm the effects of SB on cognition in older adults. Public health campaigns should be targeted at displacing high levels of television viewing, in excess of 3.5hours/day among older adults.

Introduction

Participation in sedentary behaviour may pose risk to health outcomes in adults including all-cause mortality, cardiovascular disease mortality, cardiovascular disease incidence, cancer mortality, cancer incidence, type 2 diabetes incidence and depression (Biswas & Alter, 2015; Vancampfort et al., 2020). By sedentary behaviour, we refer to any waking behaviour characterised by energy expenditure of ≤ 1.5 METs in reclining, lying and sitting postures (Tremblay et al., 2017). Even when adults engage in physical activity, their sedentary levels could still be detrimental to health. A harmonised meta-analysis of over 1 million men and women suggested that high levels of siting were associated with increased risk of death and only high levels of moderate intensity physical activity (60-75 minutes/day) appeared to mitigate this risk (Ekelund et al., 2016). Further, this review found that an increase in mortality risk was associated with viewing television for more than 3 hours a day, regardless of physical activity levels (Ekelund et al., 2016).

Despite accumulating evidence on the adverse health outcomes associated with sedentary behaviour, to date, there are only a few studies on its association with cognitive outcomes. Previous studies have indicated varying associations between various sedentary behaviours and cognitive function without clear and conclusive evidence on overall associations (Olanrewaju, Stockwell, Stubbs, & Smith, 2020). For example, some studies indicated poorer or negative cognitive associations with sedentary behaviours (Falck, Davis, & Liu-Ambrose, 2017; Garcia-Hermoso, Ramirez-Velez, Celis-Morales, Olloquequi, & Izquierdo M., 2018), some found associations with better cognitive outcomes (Kesse-Guyot et al., 2012; Kurita et al., 2018), while others have shown no associations (Čukić et al., 2018; Maasakkers et al., 2019). Furthermore, there is some evidence suggesting that the association between sedentary behaviour and cognitive function may depend on the type of sedentary behaviour (SB). For instance, television viewing was consistently reported as having poorer association with cognition in adults (Fancourt & Steptoe, 2019; Hamer & Stamatakis, 2014), while activities such as reading, puzzle and computer use were reported to offer positive benefits to cognition (Kurita et al., 2018).

The first systematic review in this field suggested there was an overall negative association between sedentary behaviours and cognitive function in adults 40 years and older (Falck et al., 2017). However, a recent review found lack of clarity in this relationship due to the methodological heterogeneity and risk of biases presented in individual studies (Olanrewaju et al., 2020). To date, studies that have evaluated this area have been predominantly cross-sectional with only five longitudinal studies (Olanrewaju et al., 2020). Of these studies, one primary study and the only study, which measured device-measured sedentary exposure followed up a cohort of 274 older participants over a two-year period found higher levels (11 hours+) of sedentary behaviours were associated with an increased risk of worse cognitive ability(Ku, Liu, Lo, Chen, & Stubbs, 2017). However, the context of the sedentary behaviours in the study was not examined and may have included behaviours (e.g. reading, computer use) known to be associated with better cognitive ability(Kurita et al., 2018). In addition, more than half of previous studies recently evaluated in the aforementioned systematic review did not adjust for physical activity and loneliness.

Evidence suggested that physical activity may attenuate the association between sedentary behaviour and cognition (Garcia-Hermoso et al., 2018), while loneliness has been shown to be associated with cognitive decline in older people(Cacioppo & Cacioppo, 2014; Zhou et al., 2019). Our study aimed to address some of these issues by analysing a well-known, ongoing large cohort study (2009-present) with a nationally representative sample of older adults (8000+ participants), adjusted for established confounders including physical activity and loneliness, accounted for missing data in regression analysis and measured SB associations with several domains of cognitive outcomes.

Thus, using data from the Irish longitudinal study on ageing (TILDA), the aim of the study was to explore: (a) the cross-sectional associations between reported sedentary behaviours and cognitive function at baseline wave 1 (sitting time) and wave 3 (television viewing time) (b) longitudinal associations between baseline sedentary behaviours and cognitive changes at 4-year (waves 1-3) and 2-year follow-up (waves 3-4) in community dwelling adults 50 years and older, while accounting for well-established socio-economic, behavioural, and health-related confounders. Studies on the potentially modifiable risk factors for cognitive decline are important given the challenge presented by the rise in dementia prevalence in most regions of the globe (Brayne & Miller, 2017). Further, there is growing evidence that behavioural risk reduction has an important role to play in dementia prevention research and public health agenda (Olanrewaju, Clare, Barnes, & Brayne, 2015)

Methods

We analysed data of the TILDA study, which is an ongoing community-based survey of older adults residing in Ireland conducted by Trinity College Dublin. Details of the survey including its sampling methods are provided elsewhere(Cronin, O'Regan, Finucane, Kearney, & Kenny, 2013; Whelan & Savva, 2013). Briefly, the first wave (W1) or the baseline survey was conducted between October 2009 and February 2011, which has since been followed by three successive waves with two-year intervals. Data from Wave 1 to 4 are currently publically available. We used data from all waves with the exception of the second wave as data collected during the second wave was limited. The target sample consisted of all individuals living in private households aged 50 and over in Ireland. Clustered random sampling was used to obtain nationally representative samples. The first wave excluded institutionalized individuals, anyone with known dementia or anyone unable to personally provide written informed consent to participate due to severe cognitive impairment. Trained personnel conducted interviews with the use of Computer Assisted Personal Interviewing (CAPI). For sensitive questions, participants were asked to fill in a self-completion questionnaire (SCQ), which was returned after the interview. The response rate of W1 was 62%, and of those who participated in W1, 84% returned the SCQ. Sampling weights were generated with respect to age, sex and educational attainment to the Quarterly National Household Survey 2010. Ethical approval for TILDA was obtained by the Faculty of Health Sciences Ethics Committee of Trinity College Dublin. Written informed consent was obtained from all participants.

Sedentary behaviours

Sedentary behaviours (SB) were measured differently between waves. Our choice of sedentary behaviours was opportunistic and based on SB variables available in TILDA data. In the first wave, participants were asked the 'sitting time' question of the widely validated International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003): "During the last 7 days, how much time (per day) did you spend sitting on a week day?". This included time spent at work, at home, while doing course work during leisure time, and commuting, and could have included time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television. However in the third wave, participants were asked how many hours they spent watching television on a typical weekday. Sedentary behaviours were analysed as categorical: Sitting (<4 hours, 4-<8 hours and ≥ 8 hours); TV viewing (<1.5 hours, 1.5-<2.5 hours, 2.5-<3.5 hours, >=3.5 hours) and continuous variables (hours/ day). Reported sitting time was based on widely used cut-offs in previous literature (Vancampfort et al., 2020). Reported TV viewing time was split into approximate quartiles for even distribution of frequency across categories (<1.5H: 22%, 1.5-<2.5H: 28%, 2.5-<3.5H:22%, >=3.5H:28%).

Cognitive outcomes

This study used three assessed domains of cognitive functions namely: verbal memory (immediate and delayed recall); global cognition; and verbal fluency. Verbal memory was measured using the 10-word task list, where participants were read a word list and asked to recall as many as possible, with scores from 0-10 (Dierckx et al., 2011). We used the average scores of the sum of immediate and delayed recall scores as verbal memory outcome. Global cognition was assessed using the Mini-Mental State Examination; a 30-point questionnaire to briefly assess orientation, memory, attention, language and visual-spatial skills (Folstein, Robins, & Helzer, 1983). Verbal fluency was assessed by asking participants to name as many animals they could think of in one minute, with the scores being the acceptable number of animals named(Whiteside et al., 2016).

Control Variables

The study included control variables based on past literature and parsimony (Fancourt & Steptoe, 2019; Kesse-Guyot et al., 2012; Nemoto et al., 2018). Sociodemographic variables included age, sex, and social class (wave 1) derived from the three-class version of the United Kingdom National Statistics Socio-economic Classification(NS-SEC) (Office for National Statistics, 2010) and employment status (wave 3). The study used the NS-SEC to categorise participants into 'higher managerial, administrative and professional', 'intermediate occupation' and 'routine and manual occupation'. Those who did not fall into any of these groups such as those who have never worked or long-term unemployed were classed as 'other'. Other control variables included social participation, physical activity, smoking, loneliness, alcohol and obesity, depression, disability and chronic conditions. Smoking status was categorised as 'never', 'past' or 'current' smoker in wave 1 and 'Yes' or 'No' to the question on whether participants currently smoked in wave 3. Alcohol was measured using the CAGE alcohol screening tool(Smart, Adlaf, & Knoke, 1991).

The CAGE scale has an ordinal scale with points varying from zero (negative screen) to a maximum of four points, which indicate excessive drinking or alcoholism. Current employment status was grouped into 'employed', 'retired' and 'other'. Social participation was a recode of question whether or not participants engaged in any groups such as a sports or social group or club, a church connected group, a self-help or charitable body or other community group or a day care centre. Physical activity was measured with the International Physical Activity Questionnaire (IPAQ) and participants were classified using WHO physical activity guidelines (150 mins/week of moderate or 75 mins/week of vigorous physical activity or 600 metabolic equivalents (MET) min of weekly moderate-to-vigorous physical activity)(Craig et al., 2003; World Health Organization, 2010). Depression was assessed using the Centre for Epidemiological Studies Depression scores (CES-D)(Radloff, 1977). Obesity was determined if body mass index (BMI), based on measured weight and height, exceeded 30 kg/m^2.

A total of 20 chronic conditions (hypertension, angina pectoris, heart attack, chronic heart failure, diabetes, stroke, transient ischaemic attack, hypercholesteremia, heart murmur, atrial arrythmia, chronic lung disease, asthma, arthritis, osteoporosis, cancer, neuropsychological problems, alcohol or substance abuse, stomach ulcer, varicose ulcers and cirrhosis/serious liver damage) were assessed based on self-report. A composite variable was derived by principal component analysis of these 20 conditions. The loneliness outcome measure used was in response to the question: 'I feel lonely: Would you say this statement describes the way you felt during the past week?: Rarely or none of the time (less than 1 day); Some or a little of the time (1-2 days); Occasionally or a moderate amount of time (3-4 days); All of the time (5-7 days). Difficulty with activities of daily living (ADL: dressing, walking, bathing, eating, getting in and out of bed, toileting) and instrumental activities of daily living (IADL: preparing a hot meal; doing household chores; shopping for groceries; making telephone calls; taking medications; managing finances) were assessed and categorised into 'not disabled', 'IADL-disability only', 'ADL disability only', and 'IADL and ADL disability'.

Statistical analyses

Cross-sectional analyses were conducted using baseline data from waves 1 (sitting) and 3 (television viewing) to account for the different sedentary exposures measured at respective periods. Outcome of cross-sectional analyses was standardised regression co-efficient of associations sedentary exposures and cognitive function in respective waves. Longitudinal analyses were performed using data collected between waves 1 and 3 (sitting and cognition) and waves 3 and 4 (television and cognition). We calculated the degree of cognitive changes between waves 1-3 and 3-4 respectively through linear regression analysis using values of each test at baseline waves (1 and 3) as independent variables, scores of cognitive tests at follow-up waves (3 and 4) as dependent variables and using their standardized residuals as measures of cognitive change (Gale et al., 2012). We restricted analyses to participants, aged 50 years and older, with complete data on selected outcomes, independent and covariate variables measured at baseline and follow-up.

Data analysed at wave 1 baseline: n=8163 and at follow up wave 3: n=5700. Data analysed at baseline 3: n=6400 and at follow up wave 4: n=3750. Analysis was conducted with Stata version 16.0 (Stata Corp LP, College Station, Texas). We used a mix of univariate and bivariate analyses to present a summary of the characteristics of participants. Statistical means and standard deviations (SD) were used to describe continuous variables, while percentages described categorical variables. Descriptive characteristics of independent variables were compared by sitting time (<4 hours, 4-<8 hours/ day and ≥ 8 hours/ day) using Chi-square, Kruskall-Wallis and Spearman rank tests.

Linear regression analyses were used to ascertain the strengths of cross-sectional associations between sedentary behaviours and cognitive outcomes at wave 1(sitting) and wave 3 (television). Preliminary analyses were performed to ensure that there was no violation of the assumption of normality. Normal distribution of the continuous, dependent variables was explored using a combination of histograms, Kernel density plots with estimation and box plots. We assessed multi-collinearity in our regression models with the variance inflation factor (VIF), taking a cut-off of 2 as exclusion. Similar analysis was used to test for longitudinal strength of association between sedentary behaviours at baseline and cognitive changes between waves (waves 1-3: sitting and waves 3-4: television).

We conducted complete case and multivariate imputation analyses. Multivariate imputation was conducted using chained equations, creating 10 imputed datasets (Lee & Carlin, 2010). We used and reported based on fully adjusted models, which controlled for the following covariates: age, sex, social participation and social class / employment, physical activity, obesity, smoking, loneliness and alcohol, disability, depression and chronic condition. The sample weighting and clustering within households were considered in our analyses in order to obtain accurate estimates using the Stata 'svy' command. We conducted subpopulation regression analyses of participants aged 65 years (n=2500) and older using fully adjusted models only. All regression results were expressed in standardised beta-coefficient and p-values <0.05 was considered to be statistically significant.

Results

Baseline characteristics (wave 1: weekday-sitting)

Baseline characteristics at wave 1 are provided in Table 1. The mean (SD) age of participants at wave 1 (n=8163) was 63.5 (9.2) years. Reported mean weekday-sitting time/day was 295(159) minutes. Overall, 34%, 50% and 16% of participants reported sitting time of <4 hours, 4-<8 hours/ day and ≥ 8 hours/ day respectively. Higher levels of reported sitting showed significant but weak correlations with depression (r=0.1, P<0.0001) and lower cognitive performance (r=-0.1, P<0.0001) with the exception of global scores, which did not show significant correlation (r=-0.001, P=0.8). Participation in higher sitting levels more likely in older age groups (Chi2(3)=131.9, P<0.01). Higher levels of reported sitting during the weekday were likely to occur in participants with higher alcohol intake, smoking, depression, loneliness, not engaging in social participation, and living without disability.

Compared with their male counterpart, more female participants engaged in sitting time of <4hours and 4-<8hours/day, while male participants were likely to engage in sitting time > 8 hours/day. Participants reporting higher levels of sitting were unlikely to have met recommended physical activity except in the lowest category (0-4 hours/day), where more participants (58.6%) reported meeting recommended levels of physical activity (Table 1). Lower cognitive performances were more likely in participants not engaging in social activities, not meeting physical activity recommendation, in a routine and manual occupation, in older age groups (70+ years), with ADL and IADL disability (Table 2).

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333 Table 1: Baseline characteristics of people aged ≥50 years from the Irish Longitudinal of Ageing and their associations with
334 weekday-sitting time (wave 1, n=8163)

Characteristics	Category	Overall	Sitting time/day			Associations (P<0.01)
			<4H/day	4-<8H/day	>=8H/day	
Age (years)	50-59	40.5	47.5	35.3	42.0	**Chi2(3)=131.9, P<0.01
	60-69	30.7	32.6	31.8	23.6	
	70-79	20.0	15.1	23.2	19.9	
	>80	8.8	4.8	9.7	14.6	
Sex	Female	52.1	55.6	51.2	47.3	** Chi2(1)=22.7, P<0.0001
	Male	47.9	44.4	48.8	52.7	
Alcohol (CAGE)	0	78.1	81.5	77.2	73.6	**Chi2(4)=28.5, P<0.001
	1	10.0	8.8	10.5	10.9	
	2	7.0	5.7	7.3	8.8	
	3	3.7	3.3	3.7	4.7	
	4	1.2	0.8	1.3	2.0	
Smoker	Never	43.3	46.7	42.8	38.1	**Chi2(2)=21.3, P<0.001
	Past	38.1	36.1	38.8	40.0	
	Current	18.6	17.1	18.5	22.0	
Social Class	Routine and Manual occupations	34.5	36.9	33.2	33.6	**Chi(3)=40.9, P<0.001
	Intermediate Occupations	12.4	11.1	12.2	15.8	
	Managerial, Technical and Professional	18.9	16.7	19.4	22.0	
	Other	34.2	35.3	35.2	28.6	
Employment	Employed	35.7	41.9	30.0	40.1	**Chi2(2)=42.5, p<0.001
	Retired	35.1	28.6	39.2	36.0	
	Other	29.2	29.6	30.9	23.3	
Recommended Physical activity	No	54.3	41.4	56.7	73.6	** Chi2(1)=329.1 P<0.00001
	Yes	45.7	58.6	43.3	26.4	
Depression [a]	Mean (SD)	5.87(7.2)	5.1(6.6)	6.0(7.1)	7.3(8.5)	#rho=0.1, p<0.0001
Loneliness [b]	Rarely	80.4	83.2	80.0	76.5	**Chi2(3)=30.4, P<0.001
	Some	12.1	11.3	12.4	13.0	
	Moderate	5.2	4.1	5.7	6.0	
	All of time	2.3	1.5	2.2	4.6	
Social participation	No	54.1	52.2	53.7	59.4	*Chi2(1)=16.0, P<0.01
	Yes	45.9	47.8	46.3	40.6	
Chronic condition [c]	Mean(SD)	347.2	303.9(320.6)	363.7(341.8)	385.6(344.9)	#rho=0.1, P=0.08
Disability	Not disabled	87.0	92.2	87.3	75.0	*Chi2(3)=179.1, P<0.001
	IADL	4.0	2.4	4.0	6.7	
	ADL	4.9	3.6	5.3	6.6	
	IADL &ADL	4.1	1.8	3.4	11.7	
Verbal memory scores	Mean(SD)	14.9(4.4)	15.3(4.3)	14.8(4.4)	14.6(4.7)	#rho=-0.1 P<0.0001
Verbal Fluency	Mean(SD)	19.9(6.9)	20.3(6.8)	19.8(6.9)	19.2(7.3)	#rho=-0.1 P<0.0001
Global scores (MMSE)	Mean(SD)	28.1(2.2)	28.3(1.9)	28.1(2.3)	28.0(2.6)	#rho=-0.001 P=0.88

335 Data are in percentages unless stated otherwise.

Characteristics	Category	Cognition			Difference in means test[a] (P<0.01)*
		Verbal Memory	Verbal Fluency	Global scores	
Age (years)	50-59	16.6(3.7)	21.7(7.1)	28.7(1.7)	F(3)=475.6 P<0.0001 (VM) F(3)=214.6 P<0.0001 (VF) F(3)=234.4 P<0.0001 (MMSE)
	60-69	15.2(4.2)	20.1(6.8)	28.3(1.9)	
	70-79	13.0(4.3)	17.9(6.2)	27.5(2.5)	
	>80	10.6(3.6)	15.4(5.4)	25.6(3.2)	
Sex	Male	14.7(4.1)	20.4(6.7)	28.1(2.1)	F(1)=93.4 P<0.0001 (VM) F(1)=12.9, P<0.001 (VF) F(1)= 8.3, P<0.01 (MMSE)
	Female	15.2(4.6)	19.4(7.1)	28.2(2.4)	
Recommended Physical activity	No	14.5(4.5)	18.9(6.7)	27.9(2.4)	F(1)=102.2, P<0.0001 (VM) F(1)= 168.8, P<0.0001 (VF) F(1)=79.9, P<0.0001 (MMSE)
	Yes	15.6(4.2)	21.0(7.1)	28.4(2.0)	
Smoker	Never	15.1(4.5)	19.9(7.1)	28.2(2.3)	F(2)=7.4, P<0.001 (VM) F(2)=9.9, P<0.001 (VF) F(2)=16,9, P<0.0001 (MMSE)
	Past	14.9 (4.3)	20.2(7.0)	28.2(2.1)	
	Current	14.7 (4.2)	19.3(6.7)	27.8(2.4)	
Social participation	No	14.4(4.3)	18.9 (6.5)	27.8 (2.5)	F(1)=119.6, P<0.0001 (VM) F(1)=194.5, P<0.0001 (VF) F(1)=107.9, P<0.0001 (MMSE)
	Yes	15.5 (4.4)	20.9 (7.3)	28.4 (1.9)	
Social class	Routine and Manual Occupation	13.6 (4.1)	18.8 (6.2)	27.5 (2.4)	F(3)=195.2, P<0.0001 (VM) F(3)=118.4, P<0.0001 (VF) F(3)=133.8, P<0.0001 (MMSE)
	Intermediate Occupation	16.3 (4.3)	20.9 (7.0)	28.8 (1.5)	
	Managerial, Technical and Professional	16.7 (4.6)	22.4 (8.1)	28.9 (1.7)	
	Other	14.4 (4.1)	18.9 (6.6)	27.8 (2.3)	
Loneliness	Rarely	15.2(4.4)	20.3(7.0)	28.3(2.1)	F(3)=25.8, P<0.0001 (VM) F(3)=29.5, P<0.0001 (VF) F(3)=24.5, P<0.0001 (MMSE)
	Some	14.3(4.2)	18.6(6.9)	27.6(2.6)	
	Moderate	14.3(4.4)	18.6(6.4)	27.9(2.4)	
	All of time	12.7(4.3)	16.6(6.2)	27.1(2.9)	
Disability	Not disabled	15.3(4.2)	20.3(6.9)	28.3(2.0)	F(3)=103.6, P<0.0001 (VM) F(3)=74.9, P<0.0001 (VF) F(3)=107.1, P<0.0001 (MMSE)
	IADL	12.4(4.2)	15.9(5.9	26.9(2.8)	
	ADL	13.8(4.2)	19.1(6.9)	27.6(2.7)	
	IADL & ADL	11.4(4.5)	15.7(5.9)	25.7(3.4)	

336 (SD) standard deviation, (IADL) Instruments of Activities of Daily living, (ADL) Activities of Daily living,

337 *Kruskal Wallis test, ** Chi-square test , # Spearman's correlation test.

338 (a) Depression was measured using the Centre for Epidemiological Studies Depression scores (CES-D)

339 (b) Loneliness was measured using the University of California, Los Angeles(UCLA) Loneliness scale. Scores range from 3-9

340 (c) Composite score of 20 chronic conditions

341 Table 2: Mean cognitive function scores stratified by baseline characteristics of participants age 50+ in TILDA

Data are in mean (Standard deviation)

(IADL) Instruments of Activities of Daily living, (ADL) Activities of Daily living, (VF) (Verbal Fluency, (VM) Verbal Memory, (MMSE) Mini Mental State Scores

Verbal memory was measured using total scores from immediate and delayed recall from 10-word task list

Verbal Fluency was measured using animal naming task

Global cognitive scores were measured using Mini-mental State Examinations

aResults from one-way ANOVA test for difference in means of cognitive functions by participants' characteristic.

Television viewing (Wave 3)

The mean (SD) age of participants at wave 3 (n=6400) was 66.4(8.9) years (Table S4). Overall, reported mean weekday-television viewing time / day was 168 (101) minutes. 22%, 28%, 22% and 28% of participants reported television viewing time of <1.5H hours, 1.5-<2.5 hours/ day, 2.5-<3.5 hours/day and ≥ 3.5 hours/ day respectively. Higher levels of television viewing were associated with smoking, been retired, depression, loneliness, chronic conditions and IADL+ADL-disability. A higher proportion of participants aged 60-69 years viewed TV across all time categories compared with their younger and older counterpart.

Cross-sectional and longitudinal associations (waves 1-3: sitting)

Fully adjusted regression models did not reveal any significant cross-sectional association between reported sitting time and cognitive function. For example, analyses showed statistically insignificant associations between one-hour increase in reported sitting and cognition (verbal memory: b=0.01, CI: -0.004,0.02, P=0.30; verbal fluency: b=0.003, CI:-0.01, 0.01, P=0.55; global scores: b=0.01, CI:-0.01,0.02, P=0.39). Similarly, we did not find any association between hourly increase in baseline reported sitting time and cognitive changes between wave 1 and wave 3 (verbal memory: b=-0.001, CI: -0.02,0.01, P=0.80; verbal fluency: b=0.004, CI:-0.01, 0.02, P=0.56; global scores: b=-0.01, CI:-0.03,0.004, P=0.14) (Tables 3-5).

Cross-sectional and longitudinal associations (waves 3-4: Television viewing)

Fully adjusted and multiple imputation regression models found significant cross-sectional associations between television and poorer verbal memory (b=-0.02, CI: -0.04, -0.003, P<0.05) and poorer verbal fluency (b=-0.02, CI:-0.04,-0.002, P<0.05) with one hour increase in TV viewing per day. Sub-population analysis in 65+ years found significant association between television viewing of 3.5+ hours/day and decline in verbal fluency two years later when compared with a reference category of <1.5 hours of TV viewing (b=-0.12, CI: -0.23,-0.001, P<0.05 (SI.2)).

Table 3: Cross-sectional and longitudinal associations between sedentary behaviours (reported television viewing and sitting time: hours/day) and verbal memory estimated by multivariate imputation regression in people aged 50+ from TILDA

SB behaviour		Cross-sectional analysis	Longitudinal analysis (2 years follow-up)
Sitting[a]	Ref (<4h/day)	**n=6236**	**n=5946**
	4-<8 h/ day	0.04 (-0.01,0.10)	-0.07 (-0.14, 0.01)
	≥8 h/day	0.02 (-0.05,0.11)	0.01 (-0.10, 0.11)
Sitting[ac]	Hours /day	0.01 (-0.004, 0.02)	-0.001(-0.02, 0.01)
TV viewing[b]	Ref(<1.5h/day)	**n=6395**	**n=5655**
	1.5-<2.5 h/day	0.05 (-0.02, 0.13)	0.01 (-0.09, 0.1)
	2.5-<3.5 h/day	0.03 (-0.06, 0.12)	0.001 (-0.10, 0.11)
	≥3.5h/day	-0.04 (-0.12, 0.04)	-0.03 (-0.14, 0.07)
TV viewing[bc]	Hours /day	-0.02 (-0.04, -0.003)*	-0.001 (-0.02, 0.02)

Abbreviation: Sedentary behaviours (SB); hours (h); Television (TV)

Regression estimate is standardised beta co-efficient (confidence interval)

Fully adjusted multivariate imputation analysis using chained equations adjusted for age, sex, social class (wave 1), employment (wave 3), social participation, physical activity, obesity, smoking, loneliness, disability, depression, chronic conditions.

[a] Estimates are based on data from wave 1(cross-sectional) and waves 1 and 3 (longitudinal).

[b] Estimates are based on data from wave 3(cross-sectional) and waves 3 and 4 (longitudinal).

[ac] Sedentary behaviour (reported sitting) is measured as continuous variable and regression co-efficient refers to association of increasing hours of sitting per day with cognitive function

[bc] Sedentary behaviour (reported TV viewing) is measured as continuous variable and regression co-efficient refers to association of increasing hours of TV per day with cognitive function

* p<0.05; **p<0.01; ***p<0.001

Table 4: Cross-sectional and longitudinal associations between sedentary behaviours (reported television viewing and sitting time: categorical) and verbal fluency estimated by multivariate imputation regression in people aged 50+ from TILDA

SB behaviour		Cross-sectional analysis	Longitudinal analysis (2 years follow-up)
Sitting[a]	Ref (<4h/day)	**n=6236**	**n=5946**
	4-<8 h/ day	0.04 (-0.01, 0.10)	0.05 (-0.02, 0.12)
	≥8 h/day	0.03 (-0.06, 0.11)	0.03 (-0.07, 0.13)
Sitting[ac]	Hours /day	0.003 (-0.01, 0.01)	0.004 (-0.01, 0.02)
TV viewing[b]	Ref(<1.5h/day)	**n=6395**	**n=5655**
	1.5-<2.5 h/day	0.05 (-0.04, 0.13)	-0.05 (-0.14, 0.05)
	2.5-<3.5 h/day	0.01 (-0.08, 0.09)	-0.08 (-0.17, 0.02)
	≥3.5h/day	-0.03 (-0.11, 0.06)	-0.05 (-0.14, 0.05)
TV viewing[bc]	Hours /day	-0.02 (-0.04, -0.002)*	-0.01 (-0.03, 0.01)

Abbreviation: Sedentary behaviours (SB); hours (h); Television (TV)

Regression estimate is standardised beta co-efficient (confidence interval)

Fully adjusted multivariate imputation analysis using chained equations adjusted for age, sex, social class (wave 1), employment (wave 3), social participation, physical activity, obesity, smoking, loneliness, disability, depression, chronic conditions.

[a] Estimates are based on data from wave 1(cross-sectional) and waves 1 and 3 (longitudinal).

[b] Estimates are based on data from wave 3(cross-sectional) and waves 3 and 4 (longitudinal).

[ac] Sedentary behaviour (reported sitting) is measured as continuous variable and regression co-efficient refers to association of increasing hours of sitting per day with cognitive function

[bc] Sedentary behaviour (reported TV viewing) is measured as continuous variable and regression co-efficient refers to association of increasing hours of TV per day with cognitive function

* p<0.05; **p<0.01; ***p<0.001

Table 5: Cross-sectional and longitudinal associations between sedentary behaviours (reported television viewing and sitting time: categorical) and global cognition estimated by multivariate imputation regression in people aged 50+ from TILDA

SB behaviour		Cross-sectional analysis	Longitudinal analysis (2 years follow-up)
Sitting[a]	Ref (<4h/day)	**n=6236**	**n=5946**
	4-<8 h/ day	0.01 (-0.05, 0.08)	-0.01 (-0.09, 0.07)
	≥8 h/day	0.04 (-0.05, 0.13)	-0.09 (-0.23, 0.04)
Sitting[ac]	Hours /day	0.01 (-0.01, 0.02)	-0.01 (-0.03, 0.004)
TV viewing[b]	Ref(<1.5h/day)	**n=6395**	**n=5655**
	1.5-<2.5 h/day	0.07 (-0.01, 0.16)	0.03 (-0.07, 0.13)
	2.5-<3.5 h/day	0.04 (-0.05, 0.12)	-0.04 (-0.15, 0.07)
	≥3.5h/day	-0.01(-0.11, 0.10)	-0.02 (-0.14, 0.10)
TV viewing[bc]	Hours /day	-0.01 (-0.04, 0.01)	-0.01 (-0.04, 0.02)

Abbreviation: Sedentary behaviours (SB); hours (h); Television (TV)

Regression estimate is standardised beta co-efficient (confidence interval)

Fully adjusted multivariate imputation analysis using chained equations adjusted for age, sex, social class (wave 1), employment (wave 3), social participation, physical activity, obesity, smoking, loneliness, disability, depression, chronic conditions.

[a] Estimates are based on data from wave 1(cross-sectional) and waves 1 and 3 (longitudinal).

[b] Estimates are based on data from wave 3(cross-sectional) and waves 3 and 4 (longitudinal).

[ac] Sedentary behaviour (reported sitting) is measured as continuous variable and regression co-efficient refers to association of increasing hours of sitting per day with cognitive function

[bc] Sedentary behaviour (reported TV viewing) is measured as continuous variable and regression co-efficient refers to association of increasing hours of TV per day with cognitive function

* p<0.05; **p<0.01; ***p<0.001

Discussion

This study demonstrated that hourly increase in weekday-television viewing in community dwelling adults 50+ years has cross-sectional associations with poorer verbal memory and fluency. Further, analysis of the 65+ subpopulation showed that higher baseline television viewing for 3.5+ hours /day was associated with decline in verbal fluency two years later. These findings are in line with previous studies (Da Ronch et al., 2015; Fancourt & Steptoe, 2019; Hamer & Stamatakis, 2014; Nemoto et al., 2018) which consistently demonstrated negative associations between television viewing and cognition in middle and older aged adults. Similar to our findings, Fancourt and colleagues (Fancourt & Steptoe, 2019) showed longitudinal associations and dose response relationship between television viewing for more than 3.5 hours and semantic fluency in adults aged 50+ years. Including our research, only three studies, to date, (Fancourt & Steptoe, 2019; Hamer & Stamatakis, 2014) have explored longitudinal associations between television viewing and cognition in older adults. Possible mechanisms include low brain wave activity(Weinstein et al., 1980), associations between high multi-media tasking and reduced working memory (Uncapher, K. Thieu, & Wagner, 2016), stress created through alert-passive interaction (Lupien & Lepage, 2001), and displacement of other cognitively beneficial activities (Fancourt & Steptoe, 2018). However, television

viewing is a complex behaviour and the mode of watching has vastly moved on from traditional viewing to other equipment such as smart mobile phones, tablets and computers. Also television viewing may confer other positive effects such as education and learning, escapism and (Henning & Vorderer, 2001) perceived relaxation (Csikszentmihalyi & Kubey, 1981).

Our study did not find any associations between reported weekday-sitting and cognition. The lack of significant relationship could have been due to the complex nature and subjectivity of self-reported sitting. Sitting could occur under different contexts thereby leading to varying associations with cognition. For example cognitive activities in sitting, such as reading, puzzles, computer use have been reported to show positive relationships with cognition(Da Ronch et al., 2015; Kesse-Guyot et al., 2012; Kurita et al., 2018), while television viewing or total time spent in sitting were reported to have negative correlation(Çukić et al., 2018; Fancourt & Steptoe, 2019)**.** In addition, participation in physical activity has been shown to have attenuating effect on associations between sitting and poorer cognition, resulting in significant associations only in higher levels of reported sitting (4+ hours/day)(Garcia-Hermoso et al., 2018).

The strengths of this study include the use of data from TILDA, which has a sample of over 8000 participants followed up since 2010. There are insufficient studies that have explored longitudinal associations in this topic and more are needed to establish dose-response and causal associations. Therefore this study evaluated both cross-sectional and longitudinal associations between sedentary behaviour and cognition. We adjusted for 30 potential confounders and in particular, physical activity levels recommended by the World Health Organisation (WHO). A recent systematic review suggested that half of prior studies in this area did not adjust for physical activity in their regression analyses. A recent systematic review highlighted risk of biases in available studies such as confounding and missing data. In addition to commonly adjusted socio-demographic, behavioural and health co-variates, this study adjusted for loneliness and physical activity. Up until present time, analyses have controlled for physical activity in 50% of studies and loneliness in < 10% of studies. In addition, this study conducted multivariate imputation models to account for missing data and reduce risk of bias. Our study conducted subpopulation analyses for older adults aged 65 years and older.

The findings of this study are not without limitations. First, there may be some attrition bias due to loss of participation between waves analysed. Complete data on 3026 and 2664 participants were lost to follow-up between waves 1-3 and 3-4 respectively. Secondly, information on the trajectories of cognitive function in TILDA participants during their lifespan was not available, hence the cognitive changes between waves may not only suggest a possible decline in cognition but could also reflect their peak cognitive capacity. Thirdly, while sufficient attempt was made to control for possible confounding variables, there is still some risk of residual and unmeasured confounding in our regression analyses. Fourth, findings are restricted to reported sedentary behaviour during weekdays only. Fifth, there is evidence in literature that performance in cognitive function tests are sensitive to language skills and background. There is a possibility that a small proportion (7%) of TILDA

participants who required assistance with cognitive tests may have had English language difficulty and therefore contributed to poor performance in these tests(Carstairs, Myors, Shores, & Fogarty, 2006). Finally, both sedentary behaviour exposures were self-reported and subject to recall bias. A review of prevalence of sedentary behaviour in older people indicated an underestimation of self-reported sedentary time compared with when measured with accelerometers (Harvey, 2013). Objective and device-measured sedentary behaviour capable of accurately capturing sedentary behaviour should be considered in future studies. Further, our exposure variables measured gross sedentary time without information on the context of behavioural participation. Previous research suggested that mentally active-sedentary behaviours (computer, reading, puzzles) were associated with better mental and cognitive health outcomes when compared with passive-sedentary behaviours (TV viewing), which were associated with poorer mental and cognitive health outcomes (Hallgren et al., 2018; Kurita et al., 2018). Therefore, future studies with reported self-reported sedentary behaviour exposures should consider classifying variables using the aforementioned categories.

Conclusion

Findings of this study indicated that increase in levels of weekday-television viewing time have cross-sectional and longitudinal associations with cognition in middle-aged and older adults. However, television viewing is a complex behaviour, and health implication surrounding various contexts and modes of viewing will need to be explored in future studies. Intervention studies are needed to confirm the effect of sedentary behaviour on cognitive function in older adults. Public health education and campaign should target television viewing in excess of 3.5 hours/per day in older adults, with the objective of displacing with health promoting cognitive activities.

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Table S1: Cross-sectional and longitudinal associations between sedentary behaviours (reported television viewing and sitting time) and verbal memory estimated by multivariate imputation regression in TILDA (Subpopulation 65+ years)

SB behaviour		Cross-sectional analysis	Longitudinal analysis (2 years follow-up)
Sitting[a]	Ref(<4h/day)	**n=2772**	**n=2382**
	4-<8 h/ day	-0.009 (-0.1,0.08)	-0.05 (-0.15, 0.05)
	≥8 h/day	-0.08 (-0.2, 0.06)	0.0006 (-0.15, 0.16)
Sitting[ac]	Hours/ day	-0.01 (-.02, 0.01)	-0.01 (-0.03, 0.01)
TV viewing[b]	Ref(<1.5h/day)	**n=2563**	**n=2538**
	1.5-<2.5 h/day	0.06 (-0.05, 0.18)	-0.03 (-0.16, 0.10)
	2.5-<3.5 h/day	0.06 (-0..07, 0.19)	0.01 (-0.14, 0.10)
	≥3.5 h/day	0.003 (-0.12, 0.12)	0.02 (-0.11, 0.15)
TV viewing[bc]	Hours / day	-0.01 (-0.04, 0.01)	0.01 (-0.01, 0.04)

Abbreviation: Sedentary behaviours (SB); hours (h); Television (TV)
Regression estimate is standardised beta co-efficient (confidence interval)
Fully adjusted multivariate imputation analysis using chained equations adjusted for age, sex, social class (wave 1), employment (wave 3), social participation, physical activity, obesity, smoking, loneliness, disability, depression, chronic conditions.
[a] Estimates are based on data from wave 1(cross-sectional) and waves 1 and 3 (longitudinal).
[b] Estimates are based on data from wave 3(cross-sectional) and waves 3 and 4 (longitudinal).
[ac] Sedentary behaviour (reported sitting) is measured as continuous variable and regression co-efficient refers to association of increasing hours of sitting per day with cognitive function
[bc] Sedentary behaviour (reported TV viewing) is measured as continuous variable and regression co-efficient refers to association of increasing hours of TV per day with cognitive function
* p<0.05; **p<0.01; ***p<0.001

Table S2: Cross-sectional and longitudinal associations between sedentary behaviours (reported television viewing and sitting time) and verbal fluency estimated by multivariate imputation regression in TILDA (Subpopulation 65+)

SB behaviour		Cross-sectional analysis	Longitudinal analysis, n= (2 years follow-up)
Sitting[a]	Ref(<4h/day)	**n=2772**	**n=2382**
	4-<8 h/ day	0.03 (-0.05, 0.11)	0.06 (-0.03, 0.15)
	≥8 h/day	-0.08 (-0.21, 0.03)	0.11 (-0.01, 0.24)
Sitting[a]	Hours /day	-0.01 (-0.02, 0.01)	0.01 (-0.002, 0.03)
TV viewing[b]	Ref(<1.5h/day)	**n= 2563**	**n=2538**
	1.5-<2.5 h/ day	0.08 (-0.03, 0.19)	-0.10 (-0.21, 0.02)
	2.5-<3.5 h/day	0.06 (-0.05, 0.17)	-0.11 (-0.23, 0.003)
	≥3.5 h/day	0.01 (-0.08, 0.11)	-0.12 (-0.23, -0.001)*
TV viewing[b]	Hours /day	-0.01 (-0.03, 0.01)	-0.02 (-0.04, 0.002)

Abbreviation: Sedentary behaviours (SB); hours (h); Television (TV)
Regression estimate is standardised beta co-efficient (confidence interval)
Fully adjusted multivariate imputation analysis using chained equations adjusted for age, sex, social class (wave 1), employment (wave 3), social participation, physical activity, obesity, smoking, loneliness, disability, depression, chronic conditions.
[a] Estimates are based on data from wave 1(cross-sectional) and waves 1 and 3 (longitudinal).
[b] Estimates are based on data from wave 3(cross-sectional) and waves 3 and 4 (longitudinal).
[ac] Sedentary behaviour (reported sitting) is measured as continuous variable and regression co-efficient refers to association of increasing hours of sitting per day with cognitive function
[bc] Sedentary behaviour (reported TV viewing) is measured as continuous variable and regression co-efficient refers to association of increasing hours of TV per day with cognitive function
* p<0.05; **p<0.01; ***p<0.001

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Table S3: Cross-sectional and longitudinal associations between sedentary behaviours (reported television viewing and sitting time) and global cognition estimated by multivariate imputation regression in TILDA (Subpopulation 65+)

SB behaviour		Cross-sectional analysis	Longitudinal analysis, n= (2 years follow-up)
Sitting[a]	Ref(<4h/day)	**n=2772**	**n=2382**
	4-<8 h/ day	-0.03(-0.14, 0.07)	-0.04 (-0.16, 0.08)
	≥8 h/day	0.005(-0.16, 0.17)	0.004 (-0.16, 0.17)
Sitting[a]	Hours/ day	0.01 (-0.01, 0.03)	-0.004 (-0.03, 0.02)
TV viewing[b]	Ref(<1.5 h/day)	**n=2563**	**n=2538**
	1.5-<2.5 h/ day	0.12 (-0.03, 0.28)	-0.01 (-0.16, 0.13)
	2.5-<3.5 h/day	0.11 (-0.05, 0.26)	-0.03 (-0.17, 0.12)
	≥3.5 h /day	0.04 (-0.12, 0.21)	-0.02 (-0.17, 0.12)
TV viewing[b]	Hours /day	-0.001 (-0.03, 0.03)	-0.01 (-0.04, 0.02)

Abbreviation: Sedentary behaviours (SB); hours (h); Television (TV)

Regression estimate is standardised beta co-efficient (confidence interval)

Fully adjusted multivariate imputation analysis using chained equations adjusted for age, sex, social class (wave 1), employment (wave 3), social participation, physical activity, obesity, smoking, loneliness, disability, depression, chronic conditions.

[a] Estimates are based on data from wave 1(cross-sectional) and waves 1 and 3 (longitudinal).

[b] Estimates are based on data from wave 3(cross-sectional) and waves 3 and 4 (longitudinal).

[ac] Sedentary behaviour (reported sitting) is measured as continuous variable and regression co-efficient refers to association of increasing hours of sitting per day with cognitive function

[bc] Sedentary behaviour (reported TV viewing) is measured as continuous variable and regression co-efficient refers to association of increasing hours of TV per day with cognitive function

* p<0.05; **p<0.01; ***p<0.001

647 Table S4: Associations between TV viewing and participants characteristics (Wave 3, n=6400)

Characteristics	Category	Overall	TV time/day				Associations (P<0.01)
			<1.5H/day	1.5-<2.5H/day	2.5-<3.5H/day	>=3.5H/day	
Age (years)	50-59	25.2	34.4	29.5	22.0	18.2	**Chi2(3)= 177.6, P<0.0001
	60-69	38.5	36.0	39.0	41.4	37.6	
	70-79	21.8	16.2	20.1	23.0	25.7	
	>80	14.6	13.4	11.4	13.6	18.5	
Sex	Female	51.6	52.4	49.0	53.1	52.1	**Chi2(1)=6.5, P=0.24
	Male	48.4	47.6	51.0	46.9	47.9	
Alcohol (CAGE)	0	76.3	77.7	76.9	74.9	76.0	**Chi2 (4)=29.2, P=0.10
	1	11.9	11.7	12.0	12.5	11.4	
	2	7.4	7.3	8.2	7.8	6.4	
	3	3.6	2.4	2.5	4.0	5.0	
	4	0.8	0.9	0.4	0.8	1.2	
Smoker	No	86.6	88.1	89.5	86.0	83.6	**Chi2(1)=-30.0, P<0.01
	Yes	13.4	11.9	10.5	14.0	16.4	
Employment	Employed	30.2	44.1	40.0	27.4	15.6	**Chi2(2)=408.1, P<0.001
	Retired	48.0	38.9	42.1	50.5	56.8	
	Other	21.8	17.0	17.9	22.1	27.6	
Recommended Physical activity	No	44.2	41.3	42.6	44.2	49.1	**Chi2(2) =11.1, P=0.08
	Yes	55.8	58.7	57.4	55.8	50.9	
Depression	Mean (SD)	5.1(9.4)	4.8 (9.0)	4.8 (8.9)	5.2 (9.6)	5.5 (9.8)	#Rho=0.1, P<0.0001
Loneliness	Rarely	79.5	85.9	80.9	80.4	79.5	*Chi2(3)=60.3, P<0.001
	Some	12.3	9.4	11.1	12.6	12.3	
	Moderate	6.1	4.1	7.0	5.4	6.1	
	All of time	2.0	0.6	1.0	1.6	2.1	
Social participation	No	52.0	45.1	47.8	52.9	59.1	**Chi2(1)=78.5, P<0.0001
	Yes	48.0	54.9	52.2	47.1	40.9	
Disability	Not disabled	90.5	90.8	93.6	92.2	86.4	*Chi2(3)=33.7, P<0.001
	IADL	3.8	3.7	2.9	2.8	5.4	
	ADL	2.3	2.2	1.5	2.4	3.0	
	IADL &ADL	3.4	3.3	2.0	2.6	5.2	
Chronic condition	Mean(SD)	5(9.3)	4.8(9.0)	4.8(8.8)	5.2(9.6)	5.5(9.8)	#Rho=0.001, P<0.01

648 Data are in percentages unless stated otherwise.

649 (SD) standard deviation, (IADL) Instruments of Activities of Daily living, (ADL) Activities of Daily living,

650 *Kruskal Wallis test, ** Chi-square test , # Spearman's correlation test.

651 (a) Depression was measured using the Centre for Epidemiological Studies Depression scores (CES-D)

652 (b) Loneliness was measured using the University of California, Los Angeles(UCLA) Loneliness scale. Scores range from 3-9

653 (c) Composite score of 20 chronic conditions

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